DEPARTMENT OF GEODETIC SCIENCE

First Quarterly Progress Report

DATA ANALYSIS IN CONNECTION WITH THE NATIONAL GEODETIC SATELLITE PROGRAM

by

Ivan I. Mueller and Richard H. Rapp

[redacted]

Prepared for

National Aeronautics and Space Administration
Washington, D. C.

Period covered: April 1, 1965 - September 30, 1965
Contract No: NSR 36-008-033
OSURF Project No. 1997

The Ohio State University
Research Foundation
Columbus, Ohio

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PREFACE

This Report was prepared by Ivan I. Mueller (Principal Investigator), Associate Professor and Richard H. Rapp (Co-investigator), Assistant Professor of the Department of Geodetic Science at The Ohio State University. The execution of this research is under the technical direction of the Director, Physics and Astronomy Programs, and of the Project Manager of the National Geodetic Satellite Program, both at NASA Headquarters, Washington, D. C. The contract is administered by the Office of Grants and Research Contracts, Office of Space Science and Applications, NASA, Washington, D. C.

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1. STATEMENT OF WORK

Conduct the first year of a multi-year study and analysis of data from satellites launched specifically for geodetic purposes and from other satellites useful in geodetic studies. The program of work follows the proposal #36-008-(033) and includes analysis of positions derived from photographic observations of both reflecting and emitting satellites, from range observations, and from any other suitable types of observation. The final analysis will be an improved map placing all participating tracking stations on a single worldwide coordinate system. In deriving the final results, the Ohio State University representatives work with representatives of universities and other government agencies to prepare a single handbook compiling the best geodetic data available at the time.

The work during the first year includes but is not limited to, the following:

Task 1: Programming, testing, debugging of analysis methods.

Task 2: Participating in working groups and other planning meetings to establish desirable operational procedures including tracking procedures, participants' selection, data format, communication procedures, analysis procedures, etc.

Task 3: Providing advice to NASA on various aspects of the National Geodetic Satellite Program.

2. PERSONNEL

Ivan I. Mueller, Associate Professor, Principal Investigator,

Richard H. Rapp, Assistant Professor, Co-investigator, Edward J. Krakiwsky, Research Assistant,

Hans D. Preuss, Research Assistant.

3. REPORT ON TASK NO. 1

3.1 CAPABILITIES OF THE COMPUTER PROGRAM

3.11. General. The program is designed to accommodate observations of range and/or right ascension, declination and UT1 time of observation of a satellite of known approximate orbit-elements, or on a satellite simultaneously with other ground stations. The program yields adjusted station coordinates, and in the non-simultaneous case, adjusted orbit-elements, datum shift data, and datum rotation data.

3.12. Specific Limitations. Generally speaking, the computer must have readily available information concerning the station, datum, and observed object for every observation. This information is stored in the core during the formation of observation equations, and the finite capacity of the core necessitates the following restrictions:

Ground Stations: No more than 100 stations may be considered. Each station involves the adjustment of three unknowns (coordinates).

Orbits: A maximum of 15 orbits (which is easily increased) and their correction factors in time may be considered. An orbit is defined by expressions used by the Smithsonian Astrophysical Observatory. The number and type of factors is under the control of the user. Not more than 50 factors per orbit may be adjusted.

Datums: Up to 15 different datums may be adjusted for the three shift coordinates and the three rotation angles.

Simultaneous Sightings: A maximum of 500 mathematically stationary space objects may be observed by any number (up to 100) ground stations simultaneously. That is, a group of stations observing simultaneously an object at one given instant counts as one of the five hundred; a later set of simultaneous observations at one instant by a different group of stations on a different object counts as another. Each of the five hundred events involves as unknowns the three coordinates of the sighted object.

Bias: Ranging bias for night and day observations may be considered. These are of the form $\underline{k}R$, where R is the observed distance; they are assumed to be nearly unity. Because of the nature of the program, the night bias can never be considered alone, but always with the day bias. The day bias may be considered alone, and neither may be considered if the user so desires. The use of the words "night" and "day" are arbitrary; the bias unknowns may be used when applied to some other type of conditions.

Number of Unknowns: In addition to the restrictions noted above, no more than 1000 unknowns may be considered. That is, three times the number of stations plus three times the number of simultaneous sighting events plus the total number of orbit-elements and correction factors plus six times the number of datums plus the number of bias factors cannot exceed 1000.

Number of Observations: The number of observations is limited only by the tape length of the IBM 7094 units. Since this varies, it can only be said that the total number of observations may be huge.

3.13. Input and Output Units. The program works internally in units of days, radians, and meters. The weighting process used normalizes the observation equations into coefficients of comparable magnitude. Input units are as follows:

Station coordinates: Latitude and Longitude are in sexagesimal units. Elevation in meters.

Orbits: Ascending node, argument of perigee, inclination and mean anomaly are in angular units. Eccentricity is in radians, and the epoch of the orbit is in modified Julian Days.

Simultaneous sightings: The approximate coordinates of the object are computed from the satellite orbit, so these must be provided in the units noted above.

Datums: Major and minor ellipsoid semi-axes are in meters. Deflection components at the defining point are in sexagesimal units. Elevation of the defining point is in meters.

Observations: Right ascension is in hours, minutes, and seconds. Declination is in sexagesimal units. Range is in meters. Time is UT1, or more precisely in the system of the orbital elements. Standard error for angular observations is in sexagesimal units; for ranging in meters. These must be known for all observations, but if observations are all of the same type and to be weighted equally the weight may be set to unity or any other constant.

3.14. Output Description. The output shows corrections, corrected value, and standard error (if desired) for the unknowns in station coordinates, orbits, and bias in the units noted. The datum shift and rotation elements are also shown in this manner. The instantaneous coordinates of the satellite at the time of simultaneous observations are not shown, since they are of little general interest.

3.2. STATUS OF THE PROGRAM

The program has been written up. Presently it is being tested and modified in parts.

3.3. STRUCTURE OF THE INVESTIGATION

The structure of the investigation is shown in Figure 1 designed in co-operation with the System Sciences Corporation.

4. REPORT ON TASK NO. 2

Dr. Mueller has participated in the following meetings in connection with the project:

October 22, 1964, NASA Headquarters,

October 23, 1964, Goddard Space Flight Center,

April 1-2, 1965, NASA Headquarters,

April 20-24, 1965, Int. Symposium on Mathematical Geodesy, Turin, Italy,

April 27 - May 1, 1965, Int. Symposium on the Applications of Artificial Satellites in Geodesy, Athens, Greece.

Geodetic Satellite Geometric Analysis

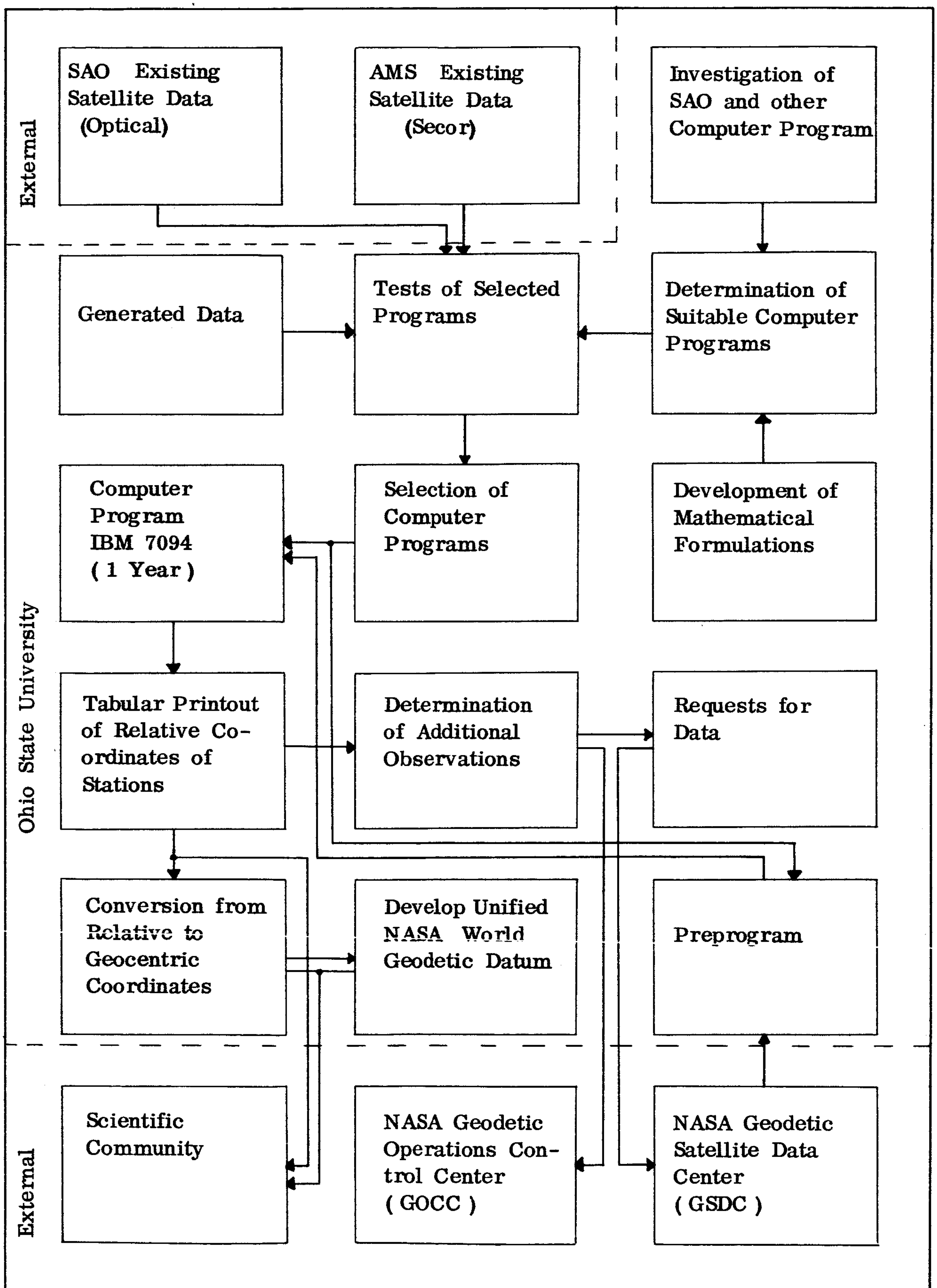

Figure 1

Dr. Rapp had a meeting with Dr. Haeffner at SAO in Cambridge, Massachusetts, on June 28, 1965.

Mr. Preuss participated in the Western National Meeting of AGU in Dallas, Texas, on September 1-3, 1965.

5. REPORT ON TASK NO. 3

Several items were discussed at the meetings listed above. Other items were handled through telephone or correspondence with the Goddard Space Flight Center, Wolf Research Corporation, System Sciences Corporation.

6. CONCLUSION

The work on the project is progressing satisfactorily. The programming phase is essentially finished. Testing and de-bugging continues using generated observations at present.

For the Department of Geodetic Science

Project Supervisor Ivan I. Mueller Date 9.20, 1965

For The Ohio State University Research Foundation

Executive Director Robert C. Stephenson AS Date 9/21, 1965